

Australian School Science Education

National Action Plan 2008 – 2012

Volume 1

The National Action Plan

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A Report Prepared for the
Department of Education, Science and Training
2007

This proposed National Action Plan has been prepared as part of a project for the Australian Government Department of Education, Science and Training. The views expressed are those of the authors and do not necessarily represent the views of the Department.

ISBN: 0 642 77688 1

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Introduction

In 2001, the Australian Government released a report, commissioned by the then Department of Education, Training and Youth Affairs, entitled *The Status and Quality of Teaching and Learning of Science in Australian Schools* (Goodrum, Hackling, & Rennie, 2001). Its recommendations included actions to address raising community awareness of science and science education; issues about teacher supply and demand, initial teacher education, professional development and professional standards; resources; assessment; and increased national collaboration. The final recommendation was that, in five years time, there be a review of the quality and status of science teaching and learning, to assess the impact of a range of initiatives in the field, including actions arising in response to the report. To a large degree, this project to develop a National Action Plan for Australian School Science Education comprises that review, and it is timely.

Since 2001, a range of initiatives has been established at national, state and local level, with funding varying from multi-million dollar national programmes (such as the *Australian School Innovation in Science, Technology and Mathematics* [ASISTM] project) to local actions funded for a few dollars. Other programmes, such as National Science Week, continue. These initiatives and programmes testify to the importance accorded to science education by governments and educational authorities at all levels, as well as the general public. And yet, in the senior secondary years, the proportion of students enrolled in science subjects continues to decline (DEST, 2006; Goodrum, et al., 2001). This, and the critical SET skills shortage that has resulted (DEST, 2006), have been the major drivers for this Action Plan. It is time to get a “big picture view” of what is currently happening in science education in Australian schools to provide a basis for determining what should happen next.

The development of the Action Plan drew on three main sources of information. The first consisted of various documents and websites, both national and international, that described trends and initiatives related to science education. In particular, major reviews consulted were *Australia’s Teachers: Australia’s Future* (Dow, 2003a, 2003b, 2003c) and the Education & Training Committee (ETC) of the Victorian Parliament’s report *Inquiry into the Promotion of Mathematics and Science Education* (ETC, 2006). The second source of information was representative persons from stakeholder groups, with data gathered using email, interviews, written responses to draft material, and other forms of personal communication. The third source was feedback obtained from the Advisory Committee and Critical Friends. All those who were approached for information and/or comment are listed in Appendix 1.

Based on information from these sources, a Background Discussion Paper was prepared and forms part of Volume 2 of this Action Plan. In addition, many initiatives related to school science education by the Australian Government, State and Territory and other authorities were mapped and this mapping is also included in Volume 2. These sources were used to assess the extent to which there is a complementarity of

effort and activity nationally, identify significant gaps in policies and programmes, and suggest actions to enhance the provision of science education and address priority needs.

The National Action Plan 2008 – 2012 begins with an overview of the nature and purpose of science education to provide a context for the following section, the state of science education in Australia. Here, a synthesis of the findings is presented in three sections addressing students and the curriculum, teacher education for science and professional learning, and systemic and community relationships. A total of eight action areas are identified, relating to curriculum, assessment, resources, initial teacher education, professional learning, teacher supply and demand, systemic issues and community resources of science learning, and actions are recommended.

The Nature and Purpose of Science Education

The fundamental purpose of school science education is to promote scientific literacy. Helping our students to become scientifically literate means helping them to understand more about science and its processes, recognise its place in our culture and society, and be able to use it in their daily lives. Thus scientific literacy is a basic need for effective citizenship. By focusing on scientific literacy, school science not only prepares students for citizenship but provides a firm basis for more specialised, discipline-based subjects in upper secondary school that lead to science courses at university, and prepares students for technical education courses that lead to science-related careers.

It is important to make clear what we mean by scientific literacy. Following their comprehensive review, Goodrum et al. (2001) argued that scientific literacy is a high priority for all citizens. They described scientifically literate people as those who are

interested in and understand the world around them, engage in the discourses of and about science, are sceptical and questioning of claims made by others about scientific matters, are able to identify questions, investigate, and draw evidence-based conclusions, and make informed decisions about the environment and their own health and well-being.

The OECD Programme for International Student Assessment (PISA), which focuses on measuring performance in language literacy, numeracy and scientific literacy, has a similar description which is at the core of its assessment in science.

An individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristics of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual and cultural environments, and willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen. (OECD, 2006, p. 12).

PISA is concerned with measuring scientific literacy in 15-year-old students and citizenship is an appropriate focus for students, even by the end of compulsory schooling. A science education that develops scientific literacy must decide what citizens should know and value in situations involving science and its role in society so that they can contribute to debate about significant science-related issues. In Australia, current issues requiring the community's awareness and understanding include our changing climate, water supplies, salination, alternative energy sources, nanotechnology, and biotechnological debate.

It is important to recognize that being scientifically literate is a cumulative process which begins with early childhood explorations and continues throughout schooling into adulthood. The kinds of teaching and learning strategies that best assist students to develop the skills and competencies of scientific literacy will vary according to the

age of the student, but science education, at all levels of schooling, should aim to contribute to its development. This requires less of the traditional, didactic pedagogies currently prevalent in our schools, particularly at the secondary level, and more of a student-centred approach that requires students to engage in active, meaningful learning. A summary of the kinds of pedagogical changes required to promote scientific literacy is shown in Appendix 2.

A Science Education to Develop Scientific Literacy

Goodrum et al. (2001) proposed nine themes to describe the “ideal” science education that would promote the development of scientific literacy.

- (1) The science curriculum is relevant to the needs, concerns and personal experiences of students.
- (2) Teaching and learning of science is centred on inquiry. Students investigate, construct and test ideas and explanations about the natural world.
- (3) Assessment serves the purpose of learning and is consistent with and complementary to good teaching.
- (4) The teaching-learning environment is characterised by enjoyment, fulfilment, ownership of and engagement in learning, and mutual respect between the teacher and students.
- (5) Teachers are life-long learners who are supported, nurtured and resourced to build the understandings and competencies required of contemporary best practice.
- (6) Teachers of science have a recognised career path based on sound professional standards endorsed by the profession.
- (7) Excellent facilities, equipment and resources support teaching and learning.
- (8) Class sizes make it possible to employ a range of teaching strategies and provide opportunities for the teacher to get to know each child as a learner and give feedback to individuals.
- (9) Science and science education are valued by the community, have high priority in the school curriculum, and science teaching is perceived as exciting and valuable, contributing significantly to the development of persons and to the economic and social well-being of the nation.

(Goodrum et al., 2001, p. vii)

These themes were kept in mind when analysing the data collected to develop this Action Plan. The evidence indicated that this picture of the ideal science education in Australian schools remains current and further, it has international support; these nine points having been chosen to demonstrate the “science education we ought to want to provide” (Gilbert, 2004, p. 9). It is also consistent with the generic frameworks

underpinning some State and Territory curricula, such as Victoria's Principles of Teaching and Learning. Consequently, it remained a corner stone of the review.

Inclusivity and the Science Curriculum

The science curriculum in Australian schools must be inclusive of all students, from pre-primary to the final years of schooling, and from all community and cultural groups. The principle of inclusivity is defined clearly in the following way in the Curriculum Framework for Western Australian schools:

Inclusivity means providing all groups of students, irrespective of educational setting, with access to a wide and empowering range of knowledge, skills and values. It means recognising and accommodating the different starting points, learning rates and previous experiences of individual students or groups of students. It means valuing and including the understandings and knowledge of all groups. It means providing opportunities for students to evaluate how concepts and constructions such as culture, disability, race, class and gender are shaped.

(Curriculum Council, 1998, p. 17)

As Goodrum et al. (2001) pointed out, "an inclusive science education means that students are offered a wide range of learning activities and a variety of assessment tasks so they can learn and demonstrate their learning in ways that suit them as individuals" (p. 27). A particular challenge, not just in science education but more broadly, is to decrease the gap between the outcomes of schooling for Indigenous and non-Indigenous students.

There is potential to incorporate Indigenous knowledge and understanding into contemporary science teaching and learning. Indigenous knowledge is broad ranging, but knowledge and understanding of nature, particularly in the areas of environmental science and sustainability, can be used as an example. The excellent Australian Bureau of Meteorology *Indigenous Weather Knowledge* website (<http://www.bom.gov.au/iwk/>) exemplifies how systematic observations by Indigenous cultures over many generations contribute to our scientific understanding. The site describes how Indigenous Australians have developed seasonal calendars based on the sequence of natural events; examples of which are:

- Flying foxes move from the inland bush to the rivers during the dry season and nest in the pandanus palm trees. When this happens the onset of rains is imminent. (Yarralin area of the Northern Territory)
- The flowering of the rough barked gum and the bunch spear grass is a sign that the winds will soon blow from the southeast and the Dry Season will arrive. (Kakadu area)

Traditionally, Indigenous communities have acquired their knowledge and understanding of the world contextually, consistent with the first two of the Goodrum et al. (2001) themes for "ideal" science education, that: the science curriculum is relevant to the needs, concerns and personal experiences of

students; and teaching and learning of science is centred on inquiry, wherein students investigate, construct and test ideas and explanations about the natural world. Though more research in this field needs to be done, such an approach may also better suit the culturally shaped learning dispositions of many Indigenous students and lead to better science learning outcomes for them.

Technology and the Science Curriculum

Although this project has as its purpose the development of an Action Plan for school *science* education, much of the literature, particularly the international literature, links science and technology. Other literature (even at primary school level) sometimes includes engineering, referring to science-engineering-technology, or SET. In this report, the focus is on science, but it is acknowledged that science and technology are often not distinguished in people's minds due to their close relationship.

Technological literacy may be described in this way:

Technologically literate people understand the designed world, its artefacts, systems and the infrastructure to maintain them; have practical skills in using artefacts and fixing simple technical problems; are able to identify practical problems, design and test solutions; recognise risks and weigh costs and benefits associated with new technologies; can evaluate, select and safely use products appropriate to their needs; and contribute to decision-making about the development and use of technology in environmental and social contexts.

(Rennie, 2003)

This definition, developed from an analysis of key documents, particularly from the UK and the US about technology education, complements the definition of scientific literacy presented earlier, and demonstrates that, given appropriate circumstances, technological and scientific literacy can develop in ways that reinforce each other. It is especially important to emphasise that the application of scientific concepts into real-life contexts demonstrates how science is linked inextricably with technology and society and developing an understanding of these relationships is an important part of developing scientific literacy.

The State of Science Education in Australian Schools

The recommendations of the Goodrum et al. (2001) report were based on five premises: the purpose of science education is to develop scientific literacy, the focus for change is closing the gap between the actual and ideal pictures of science education, teachers are the key to change, change takes time and resources, and collaboration between jurisdictions is essential for developing quality science education resources.

In the intervening years, considerable effort has been made to close some of the gaps, support teachers, provide resources and take steps towards effective collaboration between jurisdictions and between the jurisdictions and national bodies. The three-volume report of the Dow review, *Australia's Teachers, Australia's Future* (Dow, 2003a, 2003b, 2003c), whilst not limited to science teachers, provided many relevant recommendations and had outcomes such as the establishment of the National Institute for Quality Teaching and Leadership (now Teaching Australia). Together with the Australian Government Quality Teacher Programme, considerable support is provided for teachers, including science teachers, with professional learning and resources such as *Primary Connections*, a primary science through literacy programme. The Education & Training Committee of the Victorian Parliament prepared a comprehensive review, *Inquiry into the Promotion of Mathematics and Science Education* (ETC, 2006), and with most of its recommendations accepted will provide direction for science education in Victoria. Its findings have currency in a national perspective and its recommendations could be applied more widely.

Significant programmes supporting partnerships with industry and community organisations include the Australian Government-funded ASISTM project. Support for science teaching and assessment is provided by programmes such as The Le@rning Federation's digital resources and the Science Education Assessment Resources (SEAR) project. There are significant initiatives targeted at science education in the states and territories, such as the High School Development Programme for high school teachers in the Australian Capital Territory; the Essential Secondary Science Assessment programme in New South Wales aimed at improving science in the middle years; the Science Education Strategy 2006-2009 for professional learning in Queensland; Better Schools, Better Performance for science education infrastructure in Victoria; and the Primary Science Project in Western Australia.

Nationwide, there are hundreds of programmes and initiatives from very large to very small, established with funds from national, jurisdictional and other sources, and often jointly funded. A mapping exercise has been undertaken and a list of the initiatives is provided in Volume 2 of this Action Plan. These efforts are applauded and are making a significant contribution to furthering the quality of science education in Australian schools. The evidence collected for this report (provided in the Background and Discussion Paper in Volume 2), however, indicates that there still are broad gaps, and

the purpose of this Action Plan is to identify areas of weakness and recommend actions to address them.

The National Action Plan

The National Action Plan is set out in three clusters of action areas. In each action area, a brief overview of the issues is provided (the background research supporting the overview is in Volume 2) followed by recommendations for action. The first cluster of action areas relates to students and the science curriculum and foci for action are described for curriculum, assessment and resources. The second cluster relates to teacher education for science and professional learning, and the foci for action relate to initial teacher education, professional learning and teacher supply and demand. In the final cluster, broader, systemic and community issues are addressed, with actions suggested for systemic relationships and community sources of learning. Naturally there is overlap amongst the three clusters – the curriculum is not implemented independently from the teacher, for example – and so there is also some overlap amongst the recommended actions. However, the clustering is used to facilitate discussion of the issues.

In presenting the Action Plan it is noted that many of the actions suggested are consistent with recommendations made in earlier reports, particularly those by Goodrum et al. (2001), Dow (2003a) and ETC (2006). These, and other reports, have resulted in a range of actions and initiatives in all States and Territories to support and enhance the quality of science education in Australian schools. Some of the actions suggested are currently being implemented in some, but not all, parts of Australia. Thus, the intention of this Action Plan is to encourage a “stock take” of progress so far, to endorse those actions already taken, and to identify priorities for action to close gaps that remain where progress has been slow or is incomplete. Some of the actions are listed as “priority actions”, in order to identify what needs to be done immediately, with the expectation that during the five year period all actions would be implemented.

Students and the Science Curriculum

Declining Enrolments in Science

The declining proportion of the student cohort enrolling in science, particularly in the physical sciences, at the senior secondary and tertiary levels is an international phenomenon. In Australia, there is variability amongst jurisdictions, so care must be taken in making generalizations about enrolment data. Nevertheless, the generally consistent decline in proportional enrolments in the post-compulsory years of schooling is matched by declining tertiary enrolments in science-related courses and, consequently, an increasing shortage of workers with SET skills.

There is widespread belief that declining enrolments are due to students' lack of interest in school science, its perceived difficulty, and their limited understanding of the range of science-related careers and their importance. These are complex issues, however, and not easily addressed.

Lack of Interest in Science

Data from the international Relevance of Science Education (ROSE) project (Sjøberg & Schreiner, 2005) indicate that students (particularly those in developing countries) generally believe that science and technology are important, however most do not wish to become scientists. In other words, whilst students consider science and technology to be important generally, they do not see these as important to them personally.

Perceived Difficulty of Science

Science, particularly physical science, is perceived to be difficult. However, the solution cannot be to simplify science, but to assist understanding of its nature. The complexity of some scientific issues (such as ensuring sufficient water supplies in Australia) means that the answers to many science-related questions are not clear-cut. This is especially so where there is potential risk to the community. Even when the risks inherent in making a particular decision are assessable by scientists, the values used to decide whether or not the risk should be taken are often cultural, social and economic, rather than scientific. Unless there is clear communication to the public about these complex and controversial issues, the result is confusion and lack of confidence in science and scientists. In turn, this has a detrimental effect on the image of science and technology, leading to a lack of trust. School science must be structured to enable students to understand that use of science and technology is often concerned with risk and argument.

Lack of Understanding about Science

There is need for improved community understanding and awareness about science. Poor community understanding of what science is about, and what scientists do, results in ignorance about the extensive range of career options available for students

who continue their participation in science. Better programmes are required for providing accurate information regarding science careers for students, career advisors, and parents, and for more informed access to those resources that already exist. In addition, a national effort is required to encourage young people to consider taking up those careers.

Student Engagement and the Relevance of the Science Curriculum

Based on a major review of international research findings, Aikenhead (2006) concluded, “A recurring evidence-based criticism of traditional school science has been its lack of relevance for the everyday world” (p. 31). Many, but of course not all, students find the school science curriculum to be unimportant, disengaging, and irrelevant to their life interests and priorities. The culture of school science, with its traditional emphasis on what Aikenhead termed “canonical science concepts”, is at odds with these students’ self-identities, so for them science has little personal or cultural value.

Traditionally, science curricula have tried to serve two groups: the minority of students who intend to move into science-related careers, and the majority who do not but simply require sufficient scientific literacy to be sensible citizens. The outcome is that neither group is well served. Increasingly, as more students stay on at school, the traditional, academic science curriculum fails the latter group whose frequent response is to opt out of science.

One approach to serving both groups is differentiated science curricula, at least in the final years of schooling, but as yet this problem has not been solved. Attempts to introduce general, rather than discipline-specific, upper secondary science courses for tertiary entrance examinations in Australia have had marginal success because they are perceived to be of less status by teachers, career advisors, academic scientists and, consequently, by the students themselves (Fensham, 2006). Some excellent integrated science courses that do not contribute to tertiary entrance are in place, but enrolments are generally low, and there are many students beyond the compulsory years who take no science subjects.

Engaging students in science in ways that promote meaningful, rather than surface, learning cannot be achieved without curricula that are meaningful to those students. Providing a science curriculum that has personal value for all students requires differentiation, so that students can engage with content that is meaningful and satisfying with conceptual depth, rather than breadth. The curriculum must be built upon knowledge of how students learn, have demonstrable relevance to students’ everyday world, and be implemented using teaching and learning approaches that involve students in active inquiry and research. Further, a variety of inclusive teaching strategies, including teamwork as well as individual work, and integrated use of ICT, is needed to cater for the diversity now present in Australian classrooms. The teacher’s role is of paramount importance. Knowing the curriculum content and

understanding the needs of students are critical factors in implementing the curriculum in ways that engage and enthuse students.

In summary, there is a perceived lack of relevance, particularly for secondary students, in much of the current science curriculum as it is implemented in the classroom. Despite changes in curricula over the last decade, and the introduction of a range of initiatives, particularly relating to promoting links with the community, this remains a critical issue in science education. There is need to ensure that students' early experiences of school science are positive and engaging and that curricula are sufficiently flexible, interesting and relevant to meet the needs of all students, especially in the compulsory years.

The Diversity of Current Australian Science Curricula

In 1993, following a mapping of each State and Territory's curricula, a National Curriculum Statement was released, and later published, for each of eight learning areas including Science (Curriculum Corporation, 1994a, 1994b). However, each State and Territory has continued to take its own approach to curricula and most have had several revisions and some are currently revising again. State and territory investments in their own curricula are underpinned by strong belief in the suitability of each particular curriculum for its student body. National pressure for a common core curriculum (not only in science, but in other subjects) has not achieved consensus, although evidence from teachers and science educators suggests considerable support.

In April 2007, the Ministerial Council for Employment, Education, Training and Youth Affairs (MCEETYA) agreed to pursue greater national consistency in school curriculum, with common standards in English, mathematics and science initially to be developed. MCEETYA also agreed to consider the establishment of a national body to oversight development of nationally consistent curriculum, testing and reporting. MCEETYA had previously endorsed Statements of Learning in five curriculum areas, including science. The Science Statements of Learning are underpinned by a commitment to developing scientific literacy, and structured around three aspects: Science as a Human Endeavour, Science as a Way to Know, and Science as a Body of Knowledge. The documents (MCEETYA, 2006) contain Statements describing "the knowledge, skills, understandings and capacities that all young Australians should have the opportunity to learn and develop in science" (p. 3) by the end of Years 3, 5, 7, and 9. The Statements result from an attempt to have a nationally agreed, consistent core of learning opportunities within each jurisdiction's own curriculum. Under the current agreements between the Australian Government and State and Territory education authorities, these Statements of Learning must be implemented nationally from January 2008. The result is intended to be a more consistent science syllabus across jurisdictions, but with sufficient flexibility to allow accommodation to local needs.

A recent analysis by Matters and Masters (2007) reported 85–95% commonality across jurisdictions in Year 12 physics and chemistry syllabi, suggesting that it would be relatively easy in these subjects to identify a common curriculum core of content and skills that allows teachers flexibility within their own contexts. Such a step does not presently have consensus among stakeholders. A related issue at the national level is the lack of standardised descriptors for students' achievement in these upper secondary curricula.

General Competencies and the Science Curriculum

Recently, some jurisdictions have organised their curriculum framework around generic areas of learning, such as thinking, communicating, personal futures, social responsibility and world futures, rather than the readily recognizable discipline areas (including science) of, say, the 1994 National Curriculum Statement. It is not always clear where science fits in a curriculum built around these general competencies, and unless the details within these curricula refer specifically to science content, the importance of science (an ideal subject in which to develop such competencies) may be overlooked and curriculum time devoted to it decreased. Clearly, if teachers are to teach science within such a different curriculum framework, they will need considerable assistance to structure their teaching in ways that enable students to develop the scientific competencies they will need to make their way in the world as reflective citizens.

Assessment in Science Education

Assessment is often interpreted as testing the outcomes of courses or units of work. Yet, as noted in the vision of the ideal science curriculum, good assessment serves the purpose of learning. To achieve this, classroom assessment at all levels of schooling must include more than the end-of-topic tests that seem to be routine in many implemented science curricula. Senior secondary science examinations related to tertiary entrance have long reinforced a content-based, cognitively limiting approach to assessment in high schools, even down to Years 7 and 8 (Goodrum, et al., 2001). Whilst end-of-course, or summative, assessment has an important role in measuring students' achievement for the purposes of accountability and certification, other kinds of assessment are important in promoting learning within courses. Diagnostic assessment assists teachers to understand what students know and don't know and provides direction for subsequent instruction. Formative assessment is ongoing, often informal assessment that enables teachers to monitor students' progress and provide feedback to address difficulties and keep them on track to achieve the intended learning outcomes.

Successful teaching requires teachers to design evaluation activities that provide acceptable evidence of students' learning and to develop learning experiences that lead to success on those activities. By first considering what students are expected to learn and then determining how that can be measured, the design of strategies for teaching and learning can be tied closely to what students are expected to do to

demonstrate their learning. This is referred to as “backward design” in the education literature (e. g. Wiggins & McTighe, 2005).

Significant outcomes of the Science Education Assessment Resources (SEAR) project were online resources for teachers to employ better diagnostic, formative and summative assessment and a scientific literacy progress map which can be used by teachers to monitor students’ learning and demonstrate progress. This map is integral to MCEETYA’s national sample testing of Year 6 students’ scientific literacy which is to occur every 3 years from 2003 (MCEETYA, n.d.). Experience in many countries indicates that such small percentage sampling can provide effective and efficient monitoring at a national level.

In terms of quality of learning, international evidence suggests that national testing of full or large cohorts of students at particular year levels distracts teachers from teaching for scientific literacy and leads them to adopt a narrower, content-focused approach aimed at passing the national tests. It might be noted that Finland, where there are no national tests at either primary or lower secondary levels, has recorded high level PISA results in 2003 and 2006 (Eurydice, 2006).

Resources for Science Education

One characteristic of the ideal science curriculum is that excellent facilities, equipment and resources support teaching and learning. There remains, in most Australian schools, a significant gap between the actual and the ideal. Material resources which allow diversity and flexibility in teaching are essential. In primary schools, space for using and storing materials needed for science, and assistance in dealing with them, is required. Across all school levels, up-to-date ICT is stated as a significant need. There is a significant number of teachers in secondary schools who are teaching out-of-field who could be assisted by curriculum resources targeted at this level.

A comprehensive, inquiry-based science programme for the early to middle secondary school years, *Science by Doing* (SBD), was proposed in 2003 by a working group of the Prime Minister's Science, Engineering and Innovation Council (PMSEIC). Such a programme would aim to increase the engagement of junior secondary students in science learning through problem solving and student inquiry-based classroom activities. A scoping study for SBD, commissioned by the Australian Government and undertaken in 2006-07 by the Australian Academy of Science in partnership with CSIRO Education, affirmed the need for a major new junior secondary school science education programme consisting of three components (national curriculum resource, professional learning and professional learning resources). State and Territory education authorities gave in-principle support to the development of a SBD programme at the Australian Education Senior Officers Committee (AESOC) meeting in December 2006.

Australia’s geography provides significant challenges to the effective and equitable implementation of science education, not just in terms of the content of the

curriculum, but in the provision of teachers and material resources between metropolitan, provincial and remote areas, and the ability to accommodate diversity among students, particularly gifted and talented, those with a non-English-speaking background (which includes many Indigenous students) and those with special needs. The diverse cultural backgrounds of students in remote areas requires much greater flexibility for schools to determine their own resource needs, for material, support personnel and professional learning, in order to maximise student learning opportunities.

Foci for Action Relating to Students and the Science Curriculum

1. Curriculum Issues

Objective

To provide all Australian school students with access to science curricula that are relevant, contemporary and can be adapted to the needs of students in diverse situations to ensure that all students have opportunity to develop scientific literacy and become effective citizens.

Underpinning Principles

Student engagement and the development of scientific literacy will be enhanced by science curricula that are relevant to the needs, concerns and personal experiences of students. A national approach to science curricula can provide consistency in standards and also be sufficiently flexible for local needs.

Priority Actions

- 1.1 Resolve issues relating to, and develop, a common science curriculum that builds upon the Statements of Learning and retains sufficient flexibility to accommodate local needs.

Issues that need resolution include

- clarification of the place of science in a curriculum that emphasises general competencies to ensure that scientific competencies are developed, and
- uneasiness amongst some stakeholders relating to common core curricula.

- 1.2 Encourage teaching and learning approaches that promote the outcome of scientific literacy.

This can be achieved by

- providing students with opportunities to apply concepts in new situations,

- increasing the use of open-ended activities and students working in groups,
- having students learn science by seeking understanding from multiple sources of information, ranging from hands-on investigation to internet searching,
- structuring school science curriculum to enable students to understand that use of science and technology is often concerned with risk and argument, and
- improving assessment practice to measure outcomes related to scientific literacy.

Actions

- 1.3 Review the time generally devoted to science within the school curriculum with the intent of developing common guidelines which provide adequate time for science at all levels of the curriculum.

As a starting point for this review, it is suggested that the minimum time for science learning in the Primary school should be 120 minutes and in the Secondary school 180 minutes per week.

- 1.4 Develop principles and guidelines to assist in the development of inclusive science curriculum resources to more effectively meet the needs of Australia's diverse student population.

Ensuring that curricula reflect Indigenous perspectives, are flexible and culturally sensitive requires input from an expert task force to formulate principles and guidelines for effective development and implementation of resources and strategies for the teaching of science.

- 1.5 Implement strategies that provide accurate information regarding science careers and tertiary science study options (in higher education and vocational education and training institutions) for students, career advisors, and parents, and more informed access to those resources that already exist.

Successful strategies will promote awareness and understanding of science in the community as well as at all levels of schooling.

2. Assessment Issues

Objective

To improve the quality of student assessment by ensuring that it is aligned with intended learning outcomes.

Underpinning Principles

The nature of assessment practice significantly affects what science is taught and hence, what science is learned. Excellent assessment practice serves the purpose of learning and is consistent with and complementary to good teaching.

Priority Action

- 2.1 Embed the effective use of diagnostic, formative and summative assessment approaches in curriculum resource development.

Quality teaching requires effective diagnostic and formative assessment and curriculum resources must assist teachers by providing guidance in relevant assessment approaches that support learning.

Action

- 2.2 Monitor performance in science at a national level by using quality assessment instruments to sample science learning.

Continued national testing based on sampling, rather than whole cohort testing, will ensure quality measurement of science learning in an economical, viable way that provides a national picture of levels of scientific literacy without unnecessary distraction of teachers away from teaching. It will also monitor the impact of educational innovation.

3. Resource Issues

Objective

To provide quality curriculum resources that support teachers in schools in fostering effective science education.

Underpinning Principles

Quality resources are essential to quality science teaching and learning. By working cooperatively, better quality resources can be provided.

Priority Action

- 3.1 Develop national quality resources, including *Primary Connections* for the primary school years and a comprehensive, inquiry-based science programme for the early to middle secondary school years, and ensure adequate funding for their field-testing and implementation.

The development of quality resources at the national level is efficient and should be supported. This will require consultation and collaboration between the jurisdictions, and the cost savings can assist with the development, monitoring and broader implementation of the resources.

Actions

- 3.2 Develop and implement curriculum and professional learning resources for the upper secondary science areas, in particular for physics, chemistry, biology and general science.

Such professional learning resources should include a focus on the development of teachers' pedagogical content knowledge.

- 3.3 Provide assistance for teachers and a designated area for science in primary schools.

In secondary schools the provision of specialized science laboratories and laboratory assistance is generally well-established. To improve the quantity and quality of science learning in our primary schools, support is also required for these schools. Funds for spaces in which science can be taught and learned, and for science consumables should be provided routinely in primary school budgets.

- 3.4 Facilitate and coordinate the national development of educational digital publishing in providing curriculum resources.

Australia is in the process of moving from hard copy text material to the digital age. Science education can be particularly enhanced by digital innovations. Building on the cooperative endeavours of The Learning Federation, there would be value in examining how we better can meet these challenges nationally.

Teacher Education for Science and Professional Learning

The Dow review (Dow, 2003a) argued that excellence in science outcomes was dependent on quality teaching. Overall, the factors affecting the quality of science teacher graduates are those generally related to teacher education in Australian universities. These include the following challenges:

- attracting high achieving students into teacher education,
- enhancing the partnership relationships between schools and universities,
- providing adequate funding of teacher education programs,
- attracting quality teacher education staff from a teaching profession that is generally better paid than academics, and
- balancing the demands on education academics of being a good teacher and a good researcher.

A national vision is required for attracting and retaining teachers, strengthening teacher education and providing adequate professional learning.

The teacher is a critical factor in determining students' interest and motivation to learn science because it is the teacher who implements the science curriculum. The groundwork for effective teaching of science occurs during initial teacher education. Programmes, and the teacher educators who present them, must offer contemporary science education that provides adequate training in both content and pedagogy. Once they enter their own classrooms, teachers must keep abreast of changes in educational contexts and science and technological developments that affect the currency of the science curriculum. This requires opportunities for teachers to continue their professional learning.

Initial Teacher Education and Teachers' Knowledge

Four years of training is typical for Australian teachers of science, usually through a 4-year BEd, or a 3-year BSc plus 1-year DipEd. Some field experience is included to develop intending teachers' pedagogical skills. Three kinds of teacher knowledge – content knowledge, pedagogical knowledge and pedagogical content knowledge – are useful concepts in considering teachers' learning. For science teachers, these translate into knowledge of science, knowledge of how to teach, and knowledge of how to teach science.

Primary teacher education focuses on learning to teach not only science but at least five other content areas, with the focus usually on literacy and numeracy. Frequently, this leaves science content knowledge underdeveloped, with a resulting lack of confidence to teach science. This becomes a major constraint on how much science is taught at this level. Estimated averages of between 40 to 60 minutes each week are recognised as inadequate. This situation is made worse by poor resourcing of primary

schools for materials, space and assistance to look after students with special needs. With experience, good primary teachers may develop excellent pedagogical knowledge, but still have limited content knowledge in science. Pedagogical content knowledge for teaching science cannot be improved without appropriate material resources and further professional learning.

Secondary teacher education aims to develop pedagogical knowledge and pedagogical content knowledge, and usually assumes sufficient content knowledge. However, many teachers with specialized science degrees have had limited opportunity to acquire the content knowledge needed to teach general science at lower secondary level. Further, many graduating secondary teachers have had insufficient time to develop their pedagogical knowledge, which limits their pedagogical content knowledge. This also limits their ability to broaden their teaching beyond the traditional science content and connect students with science in the context of the outside world. In-service professional learning is required for teachers to remain up-to-date in terms of their content knowledge, to enhance their pedagogical content knowledge, and to promote linkages for students between science in the classroom and the science that happens outside of it.

The most common constraint in initial teacher education is decreased funding which results in reduced contact hours with students, mass lectures replacing tutorials, and a reduction of the in-school component of the teaching practicum (Lawrence & Palmer, 2003). Goodrum et al. (2001) noted a similar situation and, as the recent House of Representatives (2007) inquiry indicates, this constraint continues.

Effective Professional Learning

If there are gaps to be closed between the actual and ideal science curriculum, it is teachers who will effect the closure. Teachers are the key to change. Curriculum change requires different teaching, and for teachers to change they need professional learning supported by complementary resources. Given Australia's aging teacher workforce and the rapid changes of science and technology in society, a significant proportion of science teachers may require assistance to maintain their understanding of contemporary science and the skills to adapt their teaching to meet new challenges, especially teachers who are out-of-field or who are in provincial and remote areas.

Research into curriculum implementation and teacher change has established that effective professional learning has several requirements.

- Teachers must understand what needs to change. This requires modeling of the activities and strategies to be implemented into the classroom, showing how resources may be used to support the new approach, and demonstrating how the new approach promotes students' learning.
- Professional learning takes time, not just for attendance, but for teachers to reflect on their current practices, implement new activities/ideas/resources into

their classrooms, and then reflect upon the effects on their teaching and students' learning.

- Teacher collaboration is important. Teaching is a social activity, and curriculum change requires mutually supportive interaction amongst teachers and effective leadership, either by key teachers or administrators within the school.
- To effect changes to teachers' professional practice, they must engage in a multifaceted and long term approach to professional learning.

Whilst these principles are generally agreed, it is also important to realise that the ability of teachers to effect change following professional learning is associated with having sufficient support within their school environment.

Better provision of professional learning and incentives for teachers are required to enable them to maintain their content knowledge of contemporary science, and to improve their pedagogical and pedagogical content knowledge, particularly those inquiry-based pedagogical strategies that develop scientific literacy. In addition, providing opportunities for teachers to update their knowledge of current scientific instrumentation and the use of educational technologies would be beneficial.

Several practical aspects limit the provision of professional learning. Many teachers are reluctant to leave their classrooms to attend professional learning sessions, particularly when relief teachers are hard to find. One alternative is to hold sessions outside of school time, but there are obvious problems with this approach. Another matter concerns the location of professional learning. Whole-school, on-site sessions have benefits, including a supportive environment for the implementation of new strategies. Cross-school or regional sessions also have benefits in sharing ideas and experiences. In terms of both time and location, the best approach to professional learning may be a combination of in-school and out-of-school opportunities.

Most jurisdictions are in the process of developing, or have developed, teacher accreditation boards or institutes and have mandated requirements of professional learning for initial and continuing accreditation. Such professional learning must focus on teachers' needs, and thus be valued by them.

Australia is fortunate to have many excellent teachers of science, at both primary and secondary levels, whose students thrive in an active and challenging learning environment. Professional development including these teachers provides opportunities for them not only to share with and mentor less experienced teachers but to have time themselves to reflect and renew.

Teacher Supply and Demand

Teacher shortages in science and mathematics are becoming increasingly serious. The median age of science teachers is increasing and minority groups are under-represented. Retirement and movement of teachers to other careers threaten

Australia's teacher supply. The Australian Council of Deans of Science (Harris, et al., 2005) reported that almost 40% of early career teachers of secondary science were uncertain they would still be teaching in five years time. More detailed longitudinal data are required to clarify patterns of entrance, retention and retirement in the teaching profession to assist in workforce planning.

Two consequences of teacher shortages are that some science classes are taught by teachers without appropriate pedagogical content knowledge and with limited content knowledge, and that finding relief teachers in order for current teachers to leave their classrooms to receive professional learning is a problem, especially in rural and remote areas.

Active recruitment of teachers is a priority identified by Goodrum et al. (2001) and Dow (2003b) but is unresolved, and there is no sign that the status of teaching as a career has improved. Dow (2003b) made a number of recommendations relating to teacher retention, but there is little evidence of effective action being taken. The ACDS report examined the factors affecting retention of science teachers (Harris, et al., 2005). Many of the issues are common to teachers in other subject areas, including heavy workload (especially non-teaching work) and long hours, dealing with disaffected students, and policy decisions (such as new curricula) beyond their control. Science teachers also complained of frustration due to lack of time to prepare for practical science classes and insufficient physical resources.

Attracting new science teachers, and retaining those we have, are significant challenges, for without an adequate supply of teachers, it will be increasingly difficult to maintain quality in the profession. It is too soon to know how approaches to teacher registration and the use of professional standards will affect supply and enhance teacher quality.

Foci for Action Relating to Teacher Education for Science and Professional Learning

4. Teacher Education

Objective

To improve the quality of graduating teachers of science to ensure quality science teaching in schools.

Underpinning Principle

Graduating science teachers and teachers of science need a good understanding of science content and grounding in relevant pedagogy.

Priority Actions

- 4.1 Increase funding for initial teacher education to ensure quality training experiences.

The February 2007 *Top of the Class* report provides a series of important recommendations to improve the quality of initial teacher education including science education.

As part of initial review of the *Higher Education Support Act* 2003, the Australian Department of Education, Science and Training (DEST) is examining the impact of current discipline groupings and relativities within the funding cluster mechanism for allocating funding under the Commonwealth Grant Scheme.

- 4.2 Develop a national video databank of best practice in science pedagogy to enhance professional learning, both in pre-service and in-service environments.

An excellent databank will be expensive to develop, and should be underpinned by pedagogical research. Cooperation between Australian and New Zealand educational authorities to support this project should be considered.

Actions

- 4.3 Teacher education accreditation authorities should examine and set appropriate standards for the science content and science education requirements for primary and secondary teachers.

Without contemporary science content knowledge and relevant pedagogical skills the effectiveness of a teacher of science is greatly diminished. Both aspects are equally important for quality primary and secondary teaching.

- 4.4 Support the development of quality resources for professional learning in assessment that can assist both pre-service and in-service teachers to improve their ability to assess student learning and monitor their progress.

To improve student learning, science teachers need good exemplars that illustrate how to develop and use effectively diagnostic, formative and summative assessment. In order to use assessment to demonstrate students' progress, the science to be learned must be structured to indicate increasing levels of skills and understanding, using a mapping such as that developed in the SEAR project and used in the National Year 6 Science Assessment.

5. Professional Learning

Objective

To provide opportunities for effective, continuous professional learning for teachers of science to enable them to maintain current and high levels of content, pedagogical and pedagogical content knowledge.

Underpinning Principles

Teachers are the key to educational innovation and curriculum renewal. Time, cost, nature and location are important factors for determining the quality of professional learning

Priority Action

- 5.1 Explore the provision of financial incentives for teachers to engage in professional learning activities during “stand down” periods.

Financial rewards could be provided not as salary but as individual or school-based professional learning funds which could be drawn on by teachers to attend conferences, purchase equipment or generally use for professional purposes.

Actions

- 5.2 Establish a two-tiered structure for the provision of effective professional learning for teachers of science to maintain a balance between school-based ownership and systems leadership in effective professional learning.

Identify or establish a system of regional or jurisdictional sites that can support professional learning activities. Some examples of such centres already exist and their effectiveness should be monitored. At the same time, continue to provide opportunities for school-based, innovative professional learning programmes, as well as systemic initiatives.

- 5.3 Ensure equitable provision of professional learning to teachers in the full range of teaching locations.

Currently, teachers outside urban areas find difficulty in leaving their classrooms and there is a shortage of relief teachers for science. Early career teachers should all have the benefit of mentoring by more experienced teachers and the opportunity for focused professional development.

- 5.4 Review the current range of professional learning strategies and measures of their effectiveness with the aim of identifying those that actually improve student learning and thus obtain the maximum value for effort.

Time devoted by teachers to professional learning is valuable and should be used to best effect.

6. Teacher Supply and Demand

Objective

To recruit and retain quality science teachers so that all students have access to a quality science education.

Underpinning Principles

Attracting and retaining a sufficient number of quality teachers of science depends on effective initial teacher education, opportunities for continuous professional development, attractive remuneration and other working conditions, and a supportive and collegial work environment that allows teachers to concentrate on teaching.

Priority Actions

- 6.1 Re-examine the various pathways via which people may train (or re-train) to become teachers, particularly those pathways relating to career change, with a view to increasing options and removing barriers, whilst maintaining quality of entrants.

Employing authorities (within relevant industrial frameworks) should acknowledge the relevant knowledge and skills that new science teachers bring with them from other work experiences in determining salaries, and ensure that this acknowledgement is well publicised for potential science graduates who may wish to enter the teaching profession.

- 6.2 Examine the components of teachers' work with a view to decreasing non-teaching duties to allow more time for lesson preparation, teaching, professional learning and reflection.

Over some years the non-teaching expectations of teachers have increased to the point that they take significant time away from teaching and impose heavy emotional and administrative burdens on teachers.

- 6.3 Continue to explore avenues to make teaching more financially attractive and to retain science teachers in the profession.

Scholarships and other forms of financial assistance have been introduced for those studying to become science teachers, but further initiatives are required for those undertaking or completing such studies.

The remuneration and other conditions of service for science teachers should be reviewed and improved, especially for those engaged in rural, remote or other difficult to staff locations.

Actions

- 6.4 Collect data, on an annual basis, about the number of pre-service science teachers that enter and exit university courses, as well as the number and qualifications of science teachers registered and retention of teachers in the profession.

It is still difficult to obtain reliable baseline data about the movement into and out of the teaching profession. DEST should work with universities and jurisdictions to ensure consistent databases are in place to collect relevant data. Such data will inform discussion of the issues and facilitate action to deal with them.

6.5 Continue to explore avenues to recruit teachers and teacher aides from Indigenous and other minority groups.

The MCEETYA endorsed *National Aboriginal and Torres Strait Islander Education Policy*, which came into effect on 1 January 1990, encourages strategies for the recruitment of Indigenous teachers and teacher aides. Under the 2006 MCEETYA policy statement, *Australian Directions in Indigenous Education 2005-2008*, education systems have also agreed to provide opportunities for Indigenous teachers to develop the skills to become successful school principals and to take up other leadership positions within schools.

6.6 Examine the various processes for the continuing registration of teachers to determine how best they can contribute to maintaining the supply and quality of science teachers, particularly part-time or relief teachers.

The *National Professional Standards for Highly Competent Teachers of Science* developed by the Australian Science Teachers Association (ASTA) may be helpful in this regard.

6.7 Continue to develop a classroom teacher structure that provides a career path that recognises continual development and increasing professional skills.

Advancement along that path should not necessarily result in increased administrative or supervisory load.

Systemic and Community Relationships

In Australia there is a range of science education stakeholders who have different responsibilities and agendas. These stakeholders need to define their responsibilities more explicitly so as to minimize overlap, but also reveal gaps that point to the need for further action. A more transparent adoption of roles and more effective communication between the stakeholders will enhance cooperation and instil a sense of moving in the same direction.

Systemic Relationships

To understand the potential tensions in relationships between the stakeholders there is value in identifying some “relationship dipoles” that exist. (In science, a dipole is a pair of opposing poles or forces on a physical object; as on a bar magnet.) By considering these dipoles, responsibilities can be clarified to build a framework within which the stakeholders can work together more effectively. There are three important kinds of relationship in science education to consider.

Jurisdiction to Jurisdiction

Under the Australian constitution, education (and hence science education) is a State responsibility. Whilst there has been much value in local ownership in terms of diversity and endeavour, it has resulted in some State and Territory structures that inhibit cooperation. For example, there is considerable overlap in the content of science curriculum statements among the jurisdictions, and these often minimal differences have resulted in major problems of effective articulation, especially with regard to sharing curriculum resources. They also create disjunction for students moving between jurisdictions.

During the past decade, there has been considerable dialogue amongst the science policy officers of the various jurisdictions which has built a foundation for mutual cooperation and trust. This dialogue has occurred on an ad hoc basis and there needs to be a more formal and structured approach to cooperation at this level amongst the jurisdictions.

Nation to Jurisdiction

The need for a more national approach to education has grown as a result of the pressure to become more efficient in educational effort. The desire for a more coordinated approach is also driven by the pressures of significantly improved communication technology and the increased mobility of Australians. With a national approach to sport, television, major industries and many aspects of Australian life, it is not unrealistic to see this also reflected in education.

With the increasing costs associated with quality science resources, it is becoming apparent that some jurisdictions do not have the human and financial resources to develop these materials. There is a sensible and strong case for the cooperative

development of quality learning resources at a national level. The success of developing science learning objects by The Learning Federation (see Volume 2) is an obvious example of the potential value of cooperation between nation and jurisdictions. However, whilst the quality of the learning objects has earned praise, their implementation is not yet widespread.

School to Community

The school dimension of this dipole refers to the government and non-government school systems, within which science is taught in classrooms through the country. For the discipline of science, there are many other community organisations, at both at the national and local level, outside the formal educational system that encourage and foster science learning. At the national level there is a range of organisations that make a significant commitment of resources to science education. They include the Australian Science Teachers Association, Australian Academy of Science, CSIRO, Mineral Council of Australia, Royal Australian Chemical Institution, Australian Institute of Physics, Engineering Australia, and Questacon – The National Science and Technology Centre.

At the local level there are many different science museums (such as Scitech in Western Australia) and other centres for science learning that make a significant contribution, as well as an extensive array of different activities between schools and scientists from universities, industries and research organisations. The other important informal learning influence is the media. Science documentaries and stories in both print and electronic form have an impact on the scientific understanding of students and the images of science and scientists that they develop.

Community Sources of Science Learning

School students spend less than 20% of their waking hours in school, and less than 20% of this time will be explicitly about science. However, learning continues outside of school, and students learn about science by interacting with families and friends, by visiting institutions, such as museums, zoos, aquaria, environmental centres and similar places that have an educational aspect to their mission, from the many community and government organisations that educate the public about science-related issues, including health (e.g., skin cancer, smoking, obesity), safety (e.g., fire, electricity, chemicals) and conservation (e.g., recycling, water resources, pollution, quarantine). Most importantly, the media, particularly television and the internet, but also radio, newspapers, magazines (especially related to hobbies) and advertising, are pervasive sources of science-related information for young people. In addition to these informal sources of science learning are programmes offered by community members and institutions specifically to school students and often teachers. Some are free, some are fee-for-service, many are subsidised by various government agencies. One example is the range of Australian Government funded Cooperative Research Centres, many of which provide educational experiences for teachers, students and their communities.

Effective science education will bring school science and the out-of-school science community much closer together. This is a powerful way to enhance science learning because it shows students that science has demonstrable relevance and value to them, and provides opportunities for them to see science in action and to use science in their life outside of school. Field trips are an obvious avenue for making links between the community and the science curriculum in primary and secondary schools. Teachers can be encouraged to use field trips by including them in initial teacher education, with a focus on the pedagogical aspects which make them successful, and by assisting schools, especially at secondary level, to overcome barriers (such as timetabling issues) to taking students outside of the classroom to experience science in the real world.

Surveys of the variety of science awareness-raising activities in Australia reveal large numbers of activities for a variety of audiences, offered by providers ranging from an individual to large, national institutions. Not surprisingly, easily accessible groups, such as urban school children, are well-served but geographically remote and other groups, such as parents and the media, are less well-served. At present, there is little coordination among providers to service the broad community more effectively.

Coordination is necessary at both the national and local level. Some major national providers such as Questacon and CSIRO Education already work in complementary rather than competitive ways with coordination of regional tour schedules and in the development of new projects, and generally working together and with DEST to facilitate strategic national initiatives such as the ASISTM project. There is potential to use these organisations more extensively to augment school science education efforts nationally, particularly as both of these national organisations are grouped within the Australian education, science and training portfolio, which facilitates collaboration with DEST in relation to science education initiatives that agency funds, recently including the ASISTM Project and the *Primary Connections* programme. In contrast, at the local level, many providers have limited resources and coverage, and it is currently very difficult to coordinate availability to maximise benefits to all schools and communities.

Foci for Action in Systemic and Community Relationships

7. Systemic Relationships

Objective

To enhance the relationships and communication between the various stakeholders in science education, that is between jurisdiction and jurisdiction, nation and jurisdiction, and school and community-based educational contexts.

Underpinning Principle

Effective communication and cooperation between stakeholders will better focus energy and resources and hence improve the delivery of science education and science awareness programmes.

Priority Action

- 7.1 Establish a National Council for School Science Education. The Council could be established under the auspices of MCEETYA.

The Council should consist of national and jurisdictional representatives from the major stakeholders. The purpose of the Council would be to foster a national focus, to enable the sharing of information and to encourage innovation in science education through co-operation.

Actions

- 7.2 Establish in each jurisdiction a process to encourage cooperation amongst school systems and other stakeholders to best promote science learning within that jurisdiction.

If adequately funded, ASTA and the State Science Teachers Associations are well placed to coordinate a large number of initiatives available nationally or within jurisdictions.

- 7.3 Through MCEETYA or AESOC come to an agreement that acknowledges within a spirit of co-operation that there will be a national focus on the development of quality resources for science education and the jurisdictions will focus their energies and resources on professional learning activities and relevant local issues.

Quality resources for science curriculum, student assessment and professional learning are expensive to develop. A national approach will allow for more funding and a wider range of expertise resulting in resources of higher quality. Digital methods to distribute them can be cost efficient. Successful local uptake of these resources depends on support for their implementation.

8. Community Sources of Science Learning

Objective

To promote links with the community in school science education and to include community-related issues in the science curriculum in order to increase the relevance of science education for all students.

Underpinning Principle

Engagement in community-based, science-related issues promotes opportunities for learning science that students perceive to be relevant and worthwhile, so that learning is meaningful and lasting.

Priority Action

- 8.1 Promote linkages between science at school and community resources by establishing supporting networks to enhance opportunities for collaboration.

This could be achieved by

- appointing science officers within jurisdictions to liaise with scientific industry and research organisations to facilitate real-life experiences for teachers and students,
- providing professional learning for teachers to assist them to make better use of field trips by integrating them into school curricula, and
- engaging the science community as a resource for teachers to promote their contemporary science knowledge, by mentoring and by short term placement in science and industry.

Actions

- 8.2 Put into place processes, at both the national and jurisdictional levels, to promote equitable access to community science resources.

This could be achieved by

- establishing a national clearinghouse, managed by a national organization such as the Curriculum Corporation, to maintain a structured website documenting nationally available resources and activities to promote science in schools and the community, and
- providing a fund, perhaps managed by local Science Teachers Associations, to maintain a database of local community resources and activities to complement science at school. This could provide a means to coordinate offerings to target groups to avoid overlap and better serve the community.

- 8.3 Encourage media coverage of stories that identify science-related issues, thus promoting science, scientists and science-related careers in ways that resist stereotyping.

Communication officers within schools and school districts should work with local media to promulgate science news and achievements.

- 8.4 Identify underserved rural and remote areas and ensure adequate funding to provide outreach on a regular basis.

Important strategies would be to

- place particular focus on the promotion of science in partnership with Indigenous communities,
- maintain funding for those national programmes that have wide penetration into schools and can be implemented at the local level, and
- encourage providers of outreach programmes to promote opportunities to engage in other science and science awareness activities, such as online resources of teachers and ways to access other programmes such as *Primary Connections*.

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Appendix 1

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Stakeholders Invited to Provide Comment

Australian Academy for Technological Science and Engineering
 Australian Council for Educational Research
 Australian Council of Deans of Education
 Australian Council of Deans of Science
 Australian Education Union
 Australian Primary Principals' Association
 Australian Secondary Principals' Association
 Commonwealth Science & Industrial Research Organisation (CSIRO, Education Manager)
 Curriculum Corporation
 Department of Education (Tasmania)
 Department of Education and Children's Services (South Australia)
 Department of Education and Training (ACT)
 Department of Education and Training (Victoria)
 Department of Education and Training (Western Australia)
 Department of Education, Training and the Arts (Queensland)
 Department of Employment, Education and Training (Northern Territory)
 Director General of Department of Education and Training and Managing Director of TAFE NSW
 Early Childhood Australia, Inc
 Federation of Australian Scientific and Technological Societies
 Independent Education Union
 Professor Doug Clarke representing Critical Friends of ASISTM
 Questacon – The National Science and Technology Centre
 SiMERR (The National Centre of Science, Information and Communication Technology, and Mathematics Education for Rural and Regional Australia)
 The Le@rning Federation Secretariat
 Australasian Science Education Research Association (members forum)
 Australian Science Teachers Association (members focus groups)
 Centre for the Public Awareness of Science

Critical Friends Invited to Provide Comment

Professor Peter Fensham	Professor Julie Campbell
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Appendix 2

Changes in Emphasis Required to Teach for Scientific Literacy

Teaching for scientific literacy requires:	
Less emphasis on	More emphasis on
memorising the name and definitions of scientific terms	learning broader concepts than can be applied in new situations
covering many science topics	studying a few fundamental concepts
theoretical, abstract topics	content that is meaningful to the student's experience and interest
presenting science by talk, text and demonstration	guiding students in active and extended student inquiry
asking for recitation of acquired knowledge	providing opportunities for scientific discussion among students
individuals completing routine assignments	groups working cooperatively to investigate problems or issues
activities that demonstrate and verify science content	open-ended activities that investigate relevant science questions
providing answers to teacher's questions about content	communicating the findings of student investigations
science being interesting for only some students	science being interesting for all students
assessing what is easily measured	assessing learning outcomes that are most valued
assessing recall of scientific terms and facts	assessing understanding and its application to new situations, and skills of investigation, data analysis and communication
end-of-topic multiple choice tests for grading and reporting	ongoing assessment of work and the provision of feedback that assists learning
learning science mainly from textbooks provided to students	learning science actively by seeking understanding from multiple sources of information, including books, Internet, media reports, discussion, and hands-on investigations

(From Goodrum et al., 2001, p. 168. This format and some parts of the figure are derived from the *National Science Education Standards*, National Science Council, 1996, pp. 52, 100, 113.)